DS-2721

DETAIL SYSTEM MODEL SPECIFICATION
SATURN V S-IVB -500-ST STAGE SIMULATOR

SEPTEMBER 1968

PREPARED FOR:
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
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DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER – HUNTINGTON BEACH, CALIFORNIA

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DETAIL SYSTEM MODEL SPECIFICATION

SATURN V S-IVB-500ST STAGE SIMULATOR

1. SCOPE

This specification establishes the requirements for performance, design, and test of one type of equipment identified as the McDonnell Douglas Astronautics Company - Western Division (MDAC-WD) Saturn V S-IVB-500-ST Stage Simulator (MDAC-WD Drawing 1B45089), herein referred to as the stage simulator, to provide simulation of the Saturn S-IVB/V* flight stage for verification of the Integrated Saturn V launch vehicle. The stage simulator is shown in Figure 1.

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. These documents do not apply to the S-IVB/V stage designs which are common to the stage simulator, previously tested hardware, or standard commerical or military parts. Lower tier documents shall not be considered to be requirements which affect this design unless they are specifically referenced in this specification. In the event of conflict between documents referenced herein and this specification the detail requirements of this specification shall be considered a superseding requirement. The specification tree which reflects the relationship of various simulators to the stage simulator is shown in Figure 2.

*The S-IVB/V, as referenced herein, is based on the MDAC-WD S-IVB/V-504N configuration.

SATURN V S-IVB-500-ST STAGE SIMULATOR

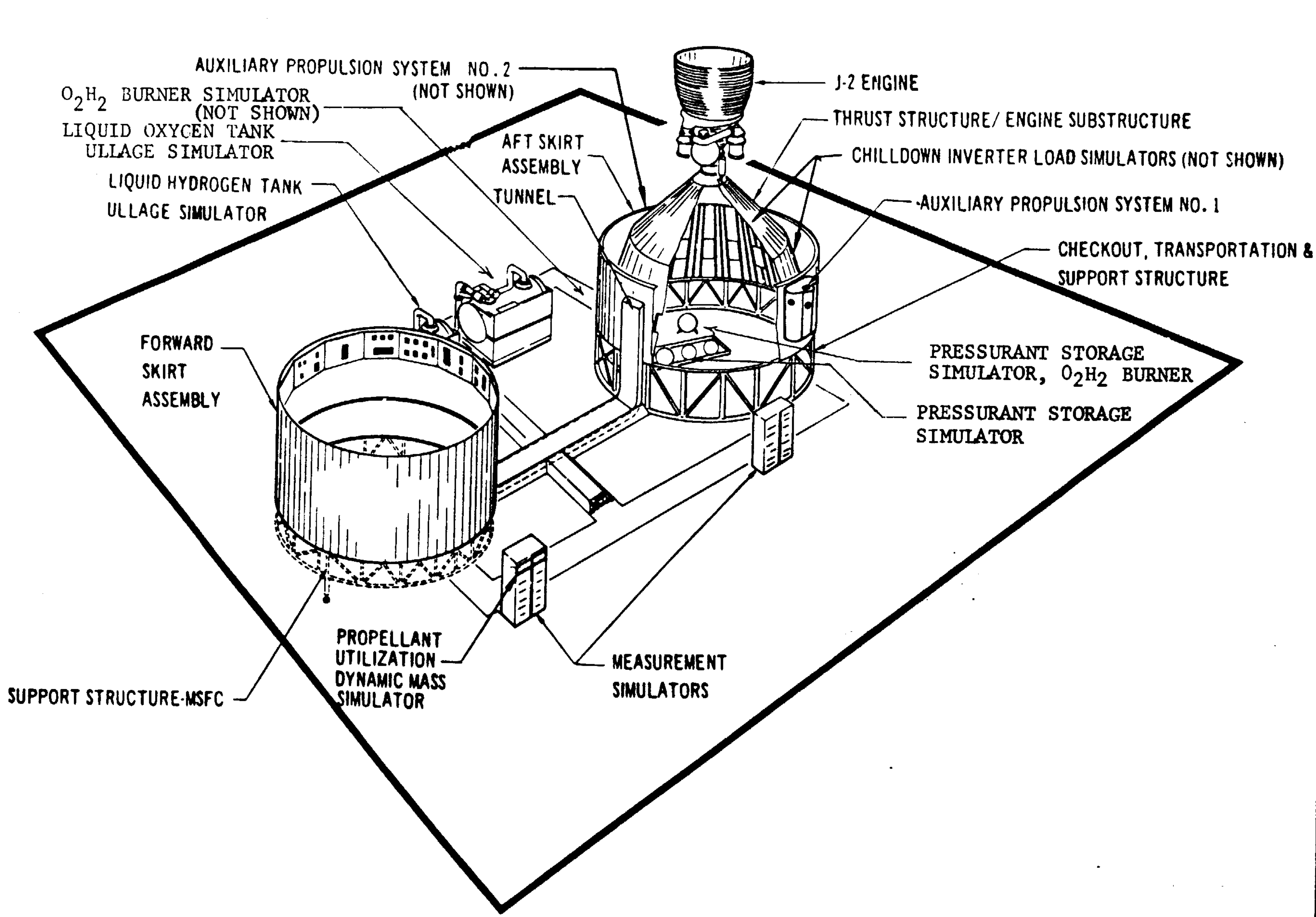

FIGURE 1

SATURN V S-IVB-500-ST STAGE SIMULATOR
SPECIFICATION TREE

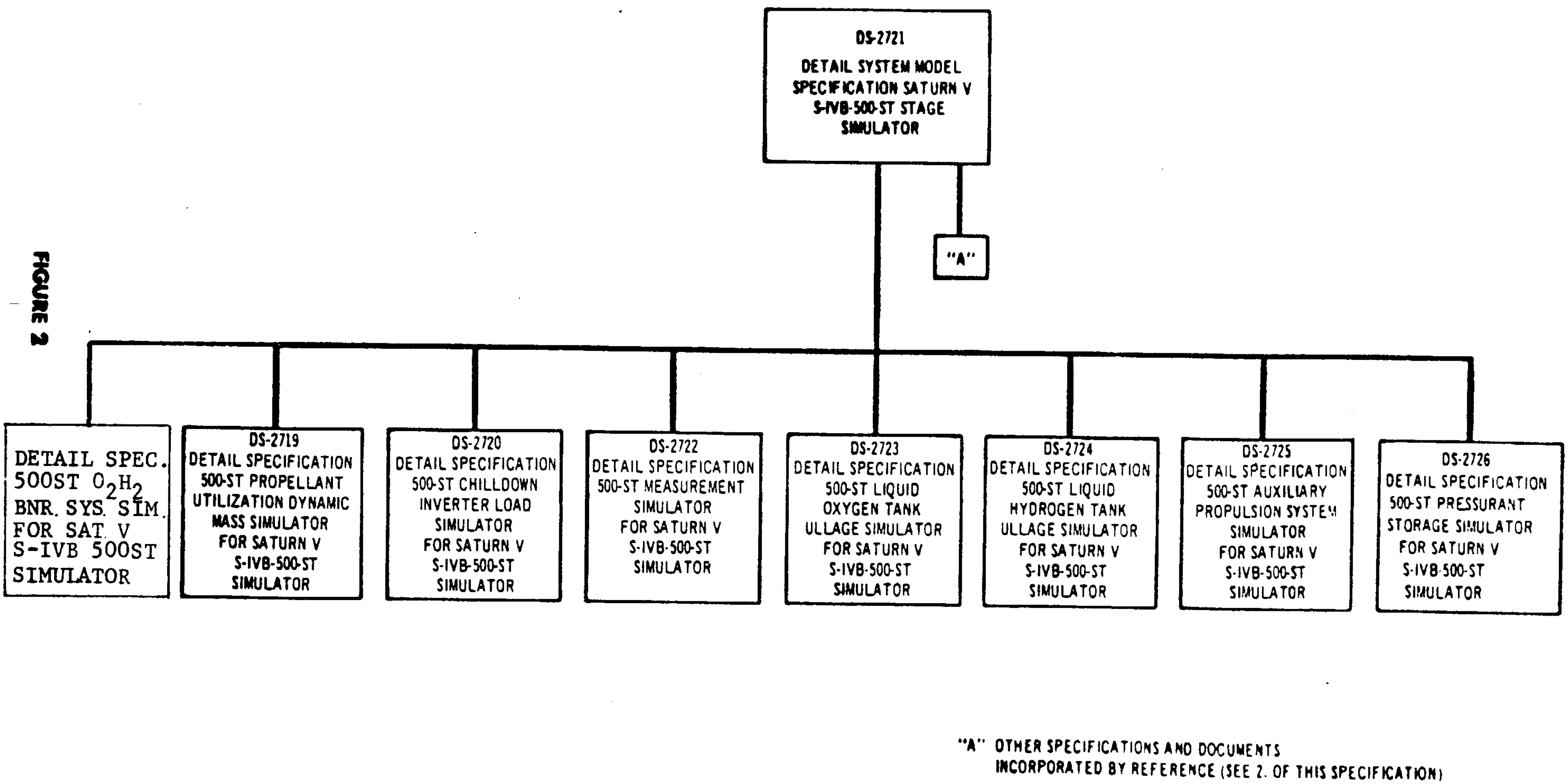

FIGURE 2

SPECIFICATIONS

Federal

QQ-A-267a 29 June 1960	Aluminum Alloy Bars, Rods, and Shapes Extruded, 2024
QQ-A-318c - Amend. 2 10 April 1961	Aluminum Alloy Plate and Sheet 5052
QQ-A-327b 7 March 1958	Aluminum Alloy Plate and Sheet 6061
O-T-620A (2) 19 February 1964	Trichloroethane, Technical, Inhibited (Methyl Chloroform)
TT-I-735a - Amend. 2 5 May 1964	Isopropyl Alcohol

Military

MIL-P-116D 29 September 1960	Preservation, Methods of
MIL-E-463B 14 May 1962	Ethyl Alcohol (for Ordnance use)
MIL-B-5087A - Amend. 1 29 January 1958	Bonding; Electrical (for Aircraft)
MIL-H-5606A 21 February 1957	Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance
MIL-P-7936B 19 December 1961	Parts and Equipment, Procedures for Packaging of

Army Ballistic Missile Agency (ABMA)

ABMA-PD-E-53 11 February 1960	Electrical Wiring Procedures

CP 209000A	Contract End Item Specification Saturn S-IVB Stage
DS-2719 1 May 1965	Detail Specification 500-ST Propellant Utilization Dynamic Mass Simulator
DS-2720 1 May 1965	Detail Specification 500-ST Chilldown Inverter Load Simulator
DS-2722 1 May 1965	Detail Specification 500-ST Measurement Simulator
DS-2723 15 May 1965	Detail Specification 500-ST Liquid Oxygen Tank Ullage Simulator
DS-2724 15 May 1965	Detail Specification 500-ST Liquid Hydrogen Tank Ullage Simulator
DS-2725 15 May 1965	Detail Specification 500-ST Auxiliary Propulsion System Simulator
DS-2726 15 May 1965	Detail Specification 500-ST Pressurant Storage Simulator
F-289J, Addendum I 10 March 1965	Finish Specification F-289 for Saturn S-IVB Stage (Saturn V and IB configurations) and Associated GSE
TBD	Detail Specification Dual Repressurization System Simulator

STANDARDS

Federal

FED-STD-102B 29 January 1963	Preservation, Packaging, and Packing Levels

Military

MIL-STD-129C-Chg. Notice 4 25 March 1963	Marking for Shipment and Storage

MIL-STD-143A 14 May 1963	Specifications and Standards, Order of Precedence for the Selection of
MIL-STD-834 20 November 1963	Packaging Data Forms, Instructions for Preparation and Use of

Marshall Space Flight Center (MSFC)

MSFC-STD-110A 16 March 1962	Electrical Hardware, Equipment, Material, and Methods, used in Saturn Ground Support Equipment
MSFC-STD-163 15 March 1962	Electrical Engineering Design Practice, Standard for

PROCEDURES

Marshall Space Flight Center (MSFC)

MSFC-PROC-158A 12 April 1962	Soldering of Electrical Connections (High Reliability), Procedure for

PUBLICATIONS

National Aeronautics and Space Administration (NASA)

NASA SP-5002 December 1963	Reliable Electrical Connections

Interstage Commerce Commission (ICC)

Tariff No. 6-C	Air Transport Restricted Articles

Issued by:
Air Traffic Conference of America
1000 Connecticut Ave., N.W.
Washington 6, D.C.

Tariff No. 15	Interstate Commerce Commission Regulations

Issued by:
T.C. George, Agent
63 Vesey Street
New York 7, New York

DRAWINGS

National Aeronautics and Space Administration (NASA)

*20M97003	J2-Engine Electrical Interface
*40M35001	Definition of Saturn V Vehicle S-IVB/ESE Electrical Interface
40M30593A	Definition of Saturn V Vehicle S-II/S-IVB Electrical Interface
*40M30597	Definition of Saturn V Vehicle S-IVB/S-V I.U. Electrical Interface

McDonnell Douglas Astronautics Company - Western Division

1A02680	Human Engineering Manual, DSV-4/DSV-4B
1A49909	Parts List - Approved for Saturn S-IVB Vehicle
1A57857	Handling Kit, Stage
1A57859	Hoist Kit, Fwd. & Aft
1A57861	Tiedown Kit, Protective Transport
1A66131	Marking and Label Requirements
1A67970	Servicer, Hydraulic, S-IVB

*and all subsequent mutaully (MDAC-WD/MSFC) authorized change orders

1B00405	Plate, Identification
1B00407	Plate, Identification
1B45011	Facilities Design Criteria Location MSFC - Alabama Saturn S-IVB-500-ST Simulator Project Bldg. 4708
1B45037	J-2 Engine Installation, Aft Section, Space Vehicle Simulator
1B45040	Function Schematic, Propulsion System, Space Vehicle Simulator
1B45041	Simulator, Tank Ullage Liquid Hydrogen
1B45042	Simulator, Tank Ullage Liquid Oxygen
1B45043	Piping Installation, Interconnecting, Space Vehicle Simulator
1B45044	Tank Assembly, Pressurization
1B45046	Pneumatic Control System Installation, Aft Section
1B45047	Tank Pressurization Systems Installation, Liquid Oxygen
1B45048	Tank Pressurization System Installation, Liquid Hydrogen
1B45049	Chilldown System Installation, Aft Section
1B45050	Propulsion System, Auxiliary
1B46252	Wiring Harness Installation, Aft Section
1B45063	Electrical Equipment Installation, Aft Section
1B46250	O_2 H_2 Burner, Installation

1B45066	Hydraulic System Installation, Aft Section
1B45089	Simulator, Space Vehicle
1B45091	Skirt, Forward Section
1B45094	Structure Assembly, Aft Section
1B45095	Thrust Structure, Aft Section
1B45101	Tunnel Section, Space Vehicle Simulator, Center
1B45110	Electrical Equipment Installation, Forward Section
1B46251	Wiring Harness Installation, Forward Section
1B46253	Wiring Harness Installation, Tunnel Section
1B45180	Advanced Functional Schematic, Control Engine Start System
1B45181	Advanced Functional Schematic, Instrumentation Engine Cutoff System
1B45182	Sequence Diagram, S-IVB/SV Stage Simulator
1B45202	Pump, Hydraulic, Auxiliary Motor Driven
1B46203	Instrumentation Program and Component List, Saturn S-IVB-500-ST/504N
1B46333	Instrumentation Program and Component List, Saturn S-IVB-500-ST/503N
1B45227	Facilities Design Criteria Saturn S-IVB-500-ST Simulator Project Location MSFC
1B45287	Advanced Functional Schematic, Propellant Utilization Loading System
1B45342	Engine Alignment Procedure

1B45343	Test Requirments, Hydraulic Actuator Assembly
1B45344	Test Requirements, Hydraulic Accumulator Reservoir Assembly
1B45345	Test Requirements, Hydraulic Subsystem S-IVB Stage/HB
1B45346	Fill, Flush, Bleed and Fluid Samples, Hydraulic System - 9001, HB
1B45356	Electrical Subsystem Checkout, Stage Simulator, VCL
1B45363	Procedure Propulsion Subsystem Checkout, MSFC Simulator
1B45697	Advanced Functional Schematic, Attitude Control System
1B45723	Advanced Functional Schematic, Propellant Utilization Flight System
1B45726	Advanced Functional Schematic, Flight Control System
1B45730	Advanced Functional Schematic, LOX Tank Pressurization System
1B45828	Advanced Functional Schematic, Fuel Tank Pressurization System
1B45829	Advanced Functional Schematic, Auxiliary Hydraulic System
1B45830	Advanced Functional Schematic, Power Distribution System
1B45831	Advanced Functional Schematic, Exploding Bridgewire System
1B45832	Advanced Functional Schematic, Data Acquisition Control System

1B45833	Advanced Functional Schematic, Range Safety System No. 1
1B45834	Advanced Functional Schematic, Range Safety System No. 2
1B46311	Advanced Functional Schematic, Instrumentation, Basic T/M and Power Distribution System
1B46312	Advanced Functional Schematic, Instrumentation, Misc. Measurements
1B46313	Advanced Functional Schematic, Instrumentation, Temp..Measurements System
1B46314	Advanced Functional Schematic, Instrumentation, Pressure Measurements System
1B46315	Advanced Functional Schematic, Instrumentation, Bi-level Measurements System
1B46317	Advanced Functional Schematic, Instrumentation, Dual Re-Pressurization System
1B45986	Interface Functions List, Vehicle
1B45422	Calibration, Simulator Consoles - H&C/O
1B46225	Preliminary Check H & C/O (Continuity Compatibility & Power On)
1B46226	Calibration, Signal Conditioning H & C/O
1B46228	Instrumentation Compatibility H & C/O
1B46229	O_2H_2 Simulator Calibration & C/O
1B46341	Continuity Check, Dual Repress. 500ST/504N/503N

1B46002	Weight and Balance Procedure DSV-4B-500-ST Simulator Stage
1B46003	Simulator, Weight and Balance Preparation, Horizontal - Huntington Beach
1P00068	Cleaning, Testing, and Handling of Space Vehicle Hydraulic System Components and Hydraulic Fluids, Procedure for
1P00071	Cleanliness for Fuel and Oxidizer Systems and Related Pneumatic Systems

3. REQUIREMENTS

3.1 Performance -

3.1.1 Functional Characteristics - The stage simulator shall represent a normal flight stage of the Saturn S-IVB/V. It shall be designed to provide simulation of electrical and mechanical functions for the purpose of verifying operation of the Integrated Saturn V launch vehicle and ground support equipment (GSE) systems at Marshall Space Flight Center (MSFC). The stage simulator shall provide propulsion, mechanical, and electrical systems of the Saturn S-IVB/V flight stage and shall also include equipment necessary to simulate dynamic functions, such as changing propellant levels, propellant flows, and pressure changes that would be experienced during vehicle checkout, loading, and flight. The various electrical subsystems shall respond to external signals in a manner nominally equal to corresponding responses from the Saturn vehicle during check-out and flight.

3.1.2 Structures -

3.1.2.1 Forward Skirt Assembly - The forward skirt assembly (MDAC-WD Drawing 1B45091) shall be a production type forward section modified to accept stage simulator mechanical and electrical installations. The skirt assembly shall be fabricated of aluminum, cylindrical in shape, and of skin and stringer type construction. The skirt assembly shall be capable of interfacing with the MSFC Instrument Unit with consideration of all electrical and electronic interface requirements.

3.1.2.2 Aft Section Structure Assembly - The aft section structure assembly (MDAC-WD Drawing 1B45094) shall consist of an aft skirt assembly, a thrust structure, a truncated conical section, and a transporation and support structure (see Figure 1). The skirt assembly shall be a production type, fabricated of aluminum, cylindrical in shape, and of skin and stringer type construction modified to accept stage simulator mechanical and electrical installations. The truncated conical section, which simulates the oxygen tank dome, shall provide for attachment to the main engine thrust structure and attachment to the forward end of the skirt assembly, and the transportation and support structure.

3.1.2.3 Thrust Structure Assembly - The thrust structure (MDAC-WD Drawing 1B45095) shall consist of a production modified type truncated cone. It shall be fabricated of aluminum and of skin and stringer type construction. The thrust structure shall be attached to the engine support fitting thereby forming an integral unit.

3.1.2.4 Tunnel - The tunnel (MDAC-WD Drawing 1B45101) shall be of modified flight configuration and shall connect between the forward and aft skirt assemblies. Tunnel connection between the forward and aft interfaces will be modified to suit installation requirements peculiar to MSFC facility (see Figure 1).

3.1.3 Propulsion System - The simulated propulsion system (MDAC-WD Drawing 1B45040, Propulsion Schematic) shall consist of the flight hardware and supplementary simulator equipment necessary to simulate the dynamic function of the S-IVB/V flight stage propulsion system during checkout, launch and flight conditions, as defined herein. The propulsion system schematic is shown in Figure 3.

3.1.3.1 Propulsion Subsystems - The simulator propulsion system is composed of several propulsion subsystems, whose functions and major components are defined as follows.

3.1.3.1.1 Pressurization and Pneumatic Control Subsystems - The pressurization and pneumatic control subsystems shall simulate the vehicle propellant tank pressure dynamics and pneumatic system control functions.

3.1.3.1.1.1 Liquid Oxygen Tank Pressurization System - The simulated liquid oxygen (LO_2) tank pressurization system consists of the regulation and control modules (cold helium fill, LO_2 tank pressurization, and LO_2 tank repressurization) mounted on the thrust structure assembly, the LO_2 tank ullage simulator, and the simulated cold helium and LO_2 tank repressurization storage vessels of the pressurant storage simulator and the simulated O_2H_2 burner system. These components provide simulated LO_2 tank pressurization and repressurization functions. The flight-type control modules are modified and re-orificed as necessary to achieve the desired flowrates for simulation of pressure dynamics by using air instead of helium. Design of the LO_2 tank pressurization system shall be in accordance with MDAC-WD Drawing 1B45047 and 1B46250. Simulation of system functions is accomplished as follows:

a. LO_2 tank prepressurization is simulated by flowing air from a ground-controlled supply through an umbilical connection, controlling the flow with the LO_2 tank pressurization control module, and maintaining the desired pressure level with a pressure switch mounted on the LO_2 tank ullage simulator.

b. The pressurant storage simulators are ASME pressure vessels which simulate the stage storage spheres. The LO_2 press sphere and the O_2H_2 burner sphere provide pressurant (air) for the first burn pressurization and for the second burn LO_2 tank repressurization utilizing the simulated O_2H_2 burner. They also supply pressure for the second burn. The LO_2 repress sphere provides pressurant (air) for the ambient helium repressurization system. The ambient system is considered to be the backup system to the O_2H_2 burner repressurization system.

c. For first burn the pressurant supply from the LO_2 press sphere and the O_2H_2 burner sphere shall be regulated and controlled by a modified flight-type LO_2 tank pressurization control module and a variable

orifice hand valve mounted on the thrust structure. Orifice sizing and adjustment procedures have been simplified by the substitution of a variable orifice hand valve in lieu of the three flight-stage orifices. The main engine heat exchanger shall be bypassed and the pressurant routed directly from the LO_2 tank pressurization control module to the LO_2 tank ullage simulator.

d. For second burn, utilizing the simulated O_2H_2 burner system, the pressurant is supplied from the LO_2 press sphere and from the O_2H_2 burner sphere. The flow is directed through the LO_2 tank pressurization control module regulator and out through the prepress port to the simulated LO_2 burner solenoid repress valves. The off command to the valves is supplied by the control pressure switch on the LO_2 ullage tank simulator.

e. For second burn, utilizing the ambient repressurization system, the pressurant is supplied from the LO_2 repress sphere. The flow is directed through the LO_2 tank repressurization control module which has an externally mounted variable orifice hand valve. When the LO_2 ullage tank simulator is fully pressurized, the tank control pressure switch supplies the ambient repress module off, command.

3.1.3.1.1.1.1 <u>Liquid Oxygen Tank Ullage Simulator</u> - Dynamic pressure histories of the S-IVB/V vehicle LO_2 tank ullage are simulated in a scaled-down 90.5 cubic foot ullage volume called the liquid oxygen tank ullage simulator. LO_2 tank prepressurization, flight pressurization, coast and repressurization simulation shall be accomplished by the corresponding pressure control modules mounted on the stage structure, and the vent/relief valve and propellant usage simulation control system mounted on the ullage simulator tank. Pressure switches, with checkout lines and fittings, mounted on the ullage simulator shall maintain the simulated pressure histories withing the normal S-IVB/V pressure control. See Figure 4 for typical pressure history. The vent and relief valve shall have the multiple function of acting as a pressure relief valve, as a controllable vent valve and as the non-propulsive vent valve.

3.1.3.1.1.1.1.1 <u>LO_2 Propellant Depletion</u> - Simulation of the propellant depletion and corresponding pressure decay are accomplished by a simulator-peculiar multiple orifice flow control system whereby pressurant flowrates from the ullage tank shall be controlled during simulated first and second burn phases. The control orifice sizes shall be manually adjustable without requiring removal from the simulator. The vent lines, as well as the pressurization and repressurization control modules, shall be re-orificed to meter the flow of air to and from the ullage tank to effect the proper simulation of pressure dynamics in conjunction with a low air rate. A low air flowrate shall minimize the storage requirements while still providing the proper dynamic simulation of the pressurization and venting cycles of the oxygen tank during simulated stage operation.

Some differences will be experienced in the actuation of the oxygen tank vent valve since the valve actuator is orificed for helium. However, the reaction time differences have been anticipated and will not impair proper simulation of the

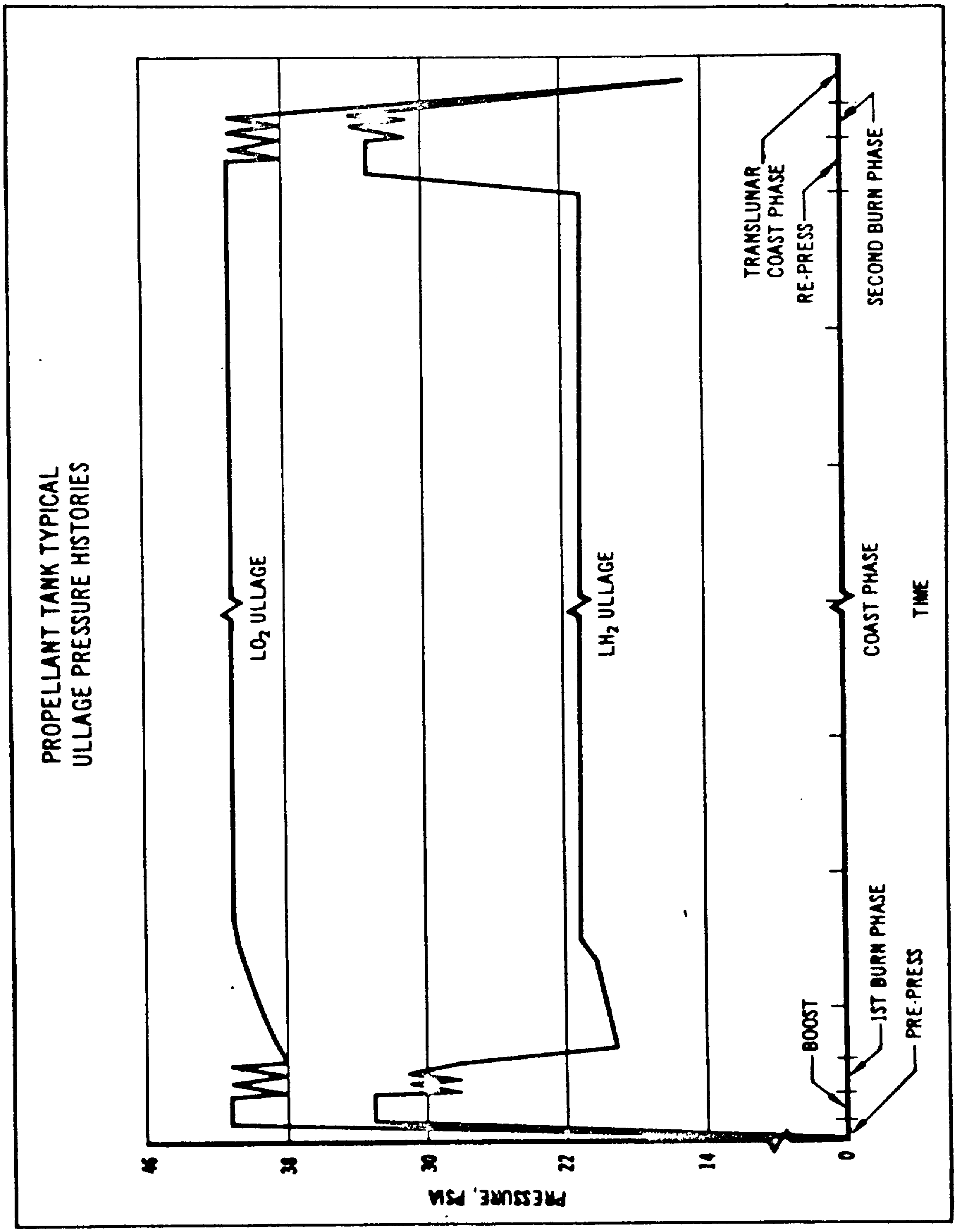
PROPELLANT TANK TYPICAL
ULLAGE PRESSURE HISTORIES
PRESSURE, PSIA
46
38
30
22
14
0
LO_2 ULLAGE
LH_2 ULLAGE
BOOST
1ST BURN PHASE
PRE-PRESS
COAST PHASE
TRANSLUNAR
COAST PHASE
RE-PRESS
SECOND BURN PHASE
TIME

FIGURE 4

total system. Design of the liquid oxygen tank ullage simulator shall be in accordance with MDAC-WD Drawing 1B45042 and MDAC-WD Specification DS-2723 (see 3.1.5.3.4 for electrical control).

3.1.3.1.1.1.1.2 LO_2 Tank Ullage Simulator Operation - Operation of the liquid oxygen tank ullage simulator during the simulated prelaunch, first burn, coast, second burn, and translunar coast phases, is as follows:

a. Prelaunch LO_2 tank prepressurization simulation shall be accomplished through the LO_2 tank pressurization control module with the ullage simulator vents and pressure decay control system closed.

b. First burn simulation shall be accomplished by alternately activating the first burn pressure decay control system and the LO_2 tank pressure control module in the following manner: Upon initiation of the first burn phase, air shall flow from the LO_2 pressurant storage vessel through the LO_2 tank pressurization control module to the LO_2 tank ullage simulator. Upon pressure switch pickup, the LO_2 tank pressure control module shall be deactivated and the first burn orifice system activated, allowing the LO_2 ullage simulator pressure to decay at a predetermined rate; upon pressure switch dropout, the first burn orifice system shall be deactivated and the LO_2 tank pressure control module re-activated and the preceding cycle repeated.

c. Upon termination of the first burn phase simulation and during the simulated coast phase, the LO_2 tank ullage simulator pressure decay control system and LO_2 tank pressurization module shall be inactive, thereby maintaining a constant LO_2 ullage simulator pressure throughout coast phase simulation.

d. Immediately prior to the second burn phase, the LO_2 tank ullage simulator shall be repressurized by the O_2H_2 burner simulator or by the ambient repressurization system as applicable.

e. On the initiation of the second burn phase, the second burn pressure decay control system (slower pressure decay rate) shall be activated in conjunction with the LO_2 tank pressure control module, and operated in the same manner as first burn simulation.

f. At termination of the second burn phase and the start of the translunar coast phase, the LO_2 pressure decay control system and the LO_2 tank pressure control module shall be inactive and the LO_2 tank ullage simulator pressure vented through the orificed LO_2 tank vent valve.

g. The N.P.V. system utilizes the vent and relief valve in a dual purpose capacity. This system on command performs all functions, both physically and electrically, which are required. The vent valve will open and remain open until given a closed command, while at the same time the original closed position indication of the vent and relief valve is electrically maintained. That is, the vent and relief valve will therefore indicate closed, while the valve is physically open on N.P.V. valve open and latch open command.

3.1.3.1.1.2 Liquid Hydrogen Tank Pressurization System - The simulated liquid hydrogen (LH_2) tank pressurization system consists of the LH_2 tank pressurization regulation and control modules mounted on the thrust structure assembly, the LH_2 tank ullage simulator, and the simulated LH_2 repressurization storage vessel of the pressurant storage simulator. The components shall provide simulated LH_2 tank pressurization and repressurization functions. The flight-type control modules shall be modified and re-orificed as necessary to achieve the desired flowrates for simulation of pressure dynamics by using air instead of helium. Design of the LH_2 tank pressurization system shall be in accordance with MDAC-WD Drawing 1B45048 (see 3.1.5.3.3 for electrical control). Simulation of system functions are as follows:

a. LH_2 ullage tank prepressurization shall be accomplished by flowing air from a ground-controlled supply through an umbilical quick-disconnect, and subsequently through the normally open first and second burn solenoid valves in the LH_2 pressurization control module.

b. Pressurant for simulated first and second burn phases shall be supplied by a facility-regulated air source through a simulator/facility-peculiar interface (auxiliary connect panel), which simulates the engine manifold gaseous hydrogen bleed. LH_2 tank pressurization simulation shall be controlled by the LH_2 tank pressurization control module. This module has been modified from the S-IVB/V vehicle configuration by resizing the first and second burn orifices to provide required simulator air flow rates, and by installing a blank orifice in the center (bypass) orifice location.

c. Simulation of LH_2 tank repressurization prior to the second burn phase shall be accomplished by using air from the pressurant storage simulator. Pressurant flows from the LO_2 press sphere and from the O_2H_2 burner sphere through the LO_2 tank pressurization control module regulator and out through the prepress port to the simulated LH_2 burner solenoid repress valves. When the LH_2 tank ullage simulator is fully pressurized the flight control and prepressure pressure switch actuation commands the LH_2 burner repress valves to close.

d. Utilization of the backup ambient repressurization system prior to second burn shall be accomplished by using air from the LH_2 repress sphere. Pressurant flows from the sphere through the LH_2 tank ambient repressurization control module which has an externally mounted variable orifice hand valve. When the LH_2 ullage tank simulator is fully pressurized, the tank control pressure switch supplies the ambient repress module off, command.

3.1.3.1.1.2.1 Liquid Hydrogen Tank Ullage Simulator - Dynamic pressure histories of the S-IVB/V vehicle LH_2 tank ullage shall be simulated in a scaled-down 90.5 cubic foot ullage volume called the liquid hydrogen tank ullage simulator. Liquid hydrogen tank prepressurization, flight pressurization, coast phase propulsive vent, and repressurization simulation shall be accomplished by the corresponding pressure control modules mounted on the thrust structure, a simulated propulsive and non-propulsive vent/relief valve system and the propellant usage simulation and makeup control system mounted on the ullage simulator tank. Pressure switches, with checkout lines and fittings mounted on the ullage simulator, maintain the simulated pressure histories within the normal S-IVB/V pressure switch control bank (see Figure 4 for typical pressure history).

3.1.3.1.1.2.1.1 LH_2 Propellant Depletion - Simulation of the propellant depletion and corresponding pressure decay shall be accomplished by a simulator-peculiar multiple orifice flow control system whereby pressurant flowrates from the ullage tank shall be controlled during simulated first and second burn phases. The control orifice sizes shall be manually adjustable without requiring removal from the simulator. The vent lines, as well as the pressurization and repressurization control modules, shall be reorificed to meter the flow of air to and from the ullage tank to effect the proper simulation of pressure dynamics in conjunction with a low air flow rate. A low air flow rate shall minimize the air storage requirements while still providing the proper dynamic simulation of the pressurization and venting cycles of the hydrogen tank during simulated stage operation.

The LH_2 tank non-propulsive vent/relief valve is a directional vent valve whereby the vented air shall be routed through the vehicle vent system or the ground closed-loop vent system to simulated actual vehicle operation. The propulsive vent control subsystem shall consist of a simulated vehicle propulsive vent shutoff valve, simulator system-peculiar flow control orifice, solenoid-operated shutoff valve, pressure switch, and propulsive vent makeup subsystem which maintains, in conjunction with the pressure switch, the ullage simulator at the hydrogen tank pressures anticipated during coast phase.

Some differences will be experienced in the actuation of the hydrogen tank vent valves since the valve actuator is orificed for helium. However, the reaction time differences have been anticipated and will not impair proper simulation of the total system. Design of the LH_2 tank ullage simulator shall be in accordance with MDAC-WD Drawing 1B45041 and MDAC-WD Specification DS-2724 (see 3.1.5.3.3).

3.1.3.1.1.2.1.2 <u>LH_2 Tank Ullage Simulator Operation</u> - Operation of the liquid hydrogen tank ullage simulator during the simulated prelaunch first burn, coast, second burn, and translunar coast phase is as follows:

a. Prelaunch LH_2 tank prepressurization simulation shall be accomplished through the LH_2 pressurization control module with the ullage simulator vents and pressure decay control system closed.

b. First burn simulation shall be accomplished by alternately activating the first burn pressure decay control system and the LH_2 tank pressure control module in the following manner: Upon initiation of the first burn phase, air shall flow from the facility air supply through the LH_2 tank pressurization control module to the LH_2 tank ullage simulator. Upon pressure switch pickup, the LH_2 tank pressure control module first burn solenoid valve shall be closed and the first burn orifice system activated, allowing the LH_2 ullage simulator pressure to decay at a predetermined rate; upon pressure switch dropout, the first burn orifice system shall be deactivated and the LH_2 tank pressure control module first burn solenoid valve open and the preceding cycle repeated.

c. Upon termination of the first burn phase simulation, and during the simulated coast phase, the LH_2 ullage simulator decay control system and LH_2 tank pressurization module shall be inactive, thereby providing a constant LH_2 ullage simulator pressure throughout coast phase simulation.

d. Upon termination of first burn simulation, the propulsive vent shutoff valve shall open and allow the pressure to decay through the in-series flow control orifice. Upon pressure decay, dropout of a pressure switch initiates the closing of a simulator-peculiar, in-series mounted shutoff valve (the simulated vehicle propulsive vent shutoff valve shall remain open per vehicle sequence) and the activation of the regulated makeup supply, which shall maintain the ullage simulator pressure at the level anticipated during the oribital coast phase.

e. Upon the termination of the oribital coast phase, the simulated vehicle propulsive vent shutoff valve is closed, the makeup supply deactivated, and the LH_2 tank ullage simulator repressurized by the LH_2 repressurization system.

f. On the initiation of the second burn phase, the second burn pressure decay control system (slower pressure decay rate) shall be activated in conjunction with the LH_2 tank pressure control module and operated in the same manner as first burn simulation.

g. At termination of the second burn phase and the start of the translunar coast phase, the LH_2 pressure decay control system and the LH_2 tank pressure control module shall be inactive and the LH_2 tank ullage simulator pressure vented through the orificed LH_2 tank non-propulsive vent valve.

3.1.3.1.1.3 Pneumatic Control System - The pneumatic control system, located on the simulator aft skirt/thrust structure assembly, consists of the ambient helium fill module and the regulation and control module required to fill the simulated pneumatic control ambient helium bottle, provide pneumatic control pressure to the valve control modules, and supply pressure to the purge control modules. Flight-type hardware is re-orificed as necessary to achieve the desired air flowrates. The ASME pressure vessel, located on the pressurant storage simulator, simulates the control ambient helium storage sphere and provides the air supply for the system. Control and regulation of the air supply is accomplished by the pneumatic power control module located on the thrust structure assembly, which distributes a regulated air supply to the following systems:

a. LO_2 tank vent valve/non-propulsive vent valve control module mounted on the LO_2 tank ullage simulator.

b. LH_2 tank vent valve control module mounted on the LH_2 tank ullage simulator.

c. LH_2 tank directional vent valve control module mounted on the LH_2 tank ullage simulator.

d. LH_2 tank continuous vent valve control module (propulsive vent) mounted on the LH_2 tank ullage simulator.

e. Chilldown system valve control module mounted on the thrust structure.

f. LO_2 and LH_2 fill and drain valve control modules mounted on the thrust structure.

g. Main engine start tank vent relief valve.

g. Engine pump purge supply module mounted on the thrust structure.

i. Chilldown pump purge supply module mounted on the simulator thrust structure.

Interconnection with the LH_2 and LO_2 ullage simulators shall be through the simulator-peculiar auxiliary connect panel.

Design of the pneumatic control system shall be in accordance with MDAC-WD Drawing 1B45046. Electrical control circuitry is as specified in MDAC-WD Specification DS-2163 with the exception of wiring relocation due to structural changes.

3.1.3.1.1.4 Pressurant Storage Simulator - The stage simulator pneumatic system consists, in part, of a pressurant storage simulator (MDAC-WD Specification DS-2726) incorporating five 3100 pounds per square inch absolute (psia) air-charged ASME pressurant storage vessels simulating the S-IVB/V eight cold helium spheres used for LO_2 tank pressurization, seven ambient helium spheres used for LH_2 repressurization, two ambient helium spheres used for LO_2 repressurization, and one ambient helium sphere used for pneumatic control. The gas storage capacity of the pressurant storage simulator is considerably less than that of the actual S-IVB/V flight vehicle system, and corresponds to the reduced amount of pressurant used for simulation of pressure dynamics. Four pressurant storage simulator pressure vessels shall be mounted on a dolly assembly which shall include relief valves, manifold tubing, associated piping required for system operation, and a separable panel containing pressure gages and hand valves. One pressurant storage vessel shall be located adjacent to structure support beam number 11. It shall be installed with a relief valve and associated piping for adequate system function. Design of the pressurant storage simulator shall be in accordance with MDAC-WD Drawing 1B45044 and 1B46250, and MDAC-WD Specification DS-2726.

3.1.3.1.1.4.1 Pressurants - The five pneumatic storage vessels shall utilize MSFC- furnished dry, filtered high purity air suitable for missile component usage (MDAC-WD recommended dew point, -125°F).

3.1.3.1.2 Main Engine Subsystem - A non-firing Rocketdyne J-2, 200,000 pound thrust engine simulator (J-206) shall be provided as GFE by NASA/MSFC for use on the stage simulator. The engine shall be capable of simulating the functions of the J-2094 engine used on the S-IVB/V flight vehicle. The main engine installation shall be in accordance with MDAC/WD Drawing 1B45037.

3.1.3.1.2.1 Mounting - The engine shall be mounted on a gimbal bearing at the approximate center of the engine chamber injector dome. Engine mounting shall provide for a seven degree gimbaling angle and allow for a 0.5 degree actuator overtravel and a 10-degree corner position.

3.1.3.1.2.2 Movement - Engine movement during gimbal maneuvers shall be accomplished by actuation of one or both of the two hydraulic actuators when commanded by the guidance section. The actuators shall be mounted 90 degrees apart (see 3.1.4.4).

3.1.3.1.2.3 Thrust Alignment - The engine shall be provided with a gimbal-bearing assembly which shall be capable of an adjustment, for lateral displacement of the imaginary geometric thrust vector of 0.250 inch in any direction.

3.1.3.1.2.4 Engine Pressurant - Engine pressurant for control purposes shall be helium in order to avoid time function problems with engine pneumatic components.

3.1.3.1.2.4.1 Pneumatic Control Pressure Vessel - Helium will be routed to the engine pneumatic control pressure vessel through the umbilical for prelaunch pressurization to 1,500 psia. The 1,500 psia pressure shall be maintained, subsequent to umbilical disconnect, by an MSFC facility-regulated helium supply routed through the simulator auxiliary connect panel. (The pressurization pressure has been reduced from 3,100 psia to 1,500 psia in order to be within ASME factors of safety, and due to this lower pressure, a makeup is required).

3.1.3.1.2.4.2 Hydrogen Start Tank - Helium, in lieu of gaseous hydrogen, shall be used to pressurize the engine hydrogen start tank to a reduced pressure of 150 psia to be compatible with ASME factors of safety.

3.1.3.1.2.4.3 Valve Sequencing - Propellant flow shall not be simulated; however, all valves shall be capable of being sequenced as required to duplicate actual engine operation.

3.1.3.1.2.4.4 <u>Thrust Chamber</u> - A ground-supplied helium purge shall be provided through an umbilical quick disconnect fitting to the thrust chamber fuel jacket.

3.1.3.1.2.4.5 <u>Liquid Oxygen and Liquid Hydrogen Turbopumps</u> - The LO_2 and LH_2 turbopump seal purges shall be simulated by missile-grade air from the vehicle pump purge module. The turbopumps shall be furnished without the internal turbine components; therefore, a modification shall be made by Rocketdyne to provide interconnection of the seal purge and outlet lines. This arrangement permits the air purge supplied by MDAC-WD to flow through the turbopump housing without pressurizing the pump housing.

3.1.3.1.2.5 <u>Main Engine Simulator-Peculiar Items</u> - The following simulator-peculiar items shall be provided to permit normal engine sequence to be accomplished:

a. An electrical signal, furnished to MSFC facility, shall be provided to simulate fuel injector temperature in order to obtain a fuel temperature "OK" indication.

b. An electrical signal, furnished by MSFC facility, shall be provided to simulate augmented spark igniter (ASI) ignition detection and shall be locked in to permit engine restart.

c. The electrical signal from the oxidizer manifold pressure switch (normally senses oxidizer injector pressure) shall be simulated by MSFC to provide "Mainstage OK" indication.

d. The hydrogen start tank shall be repressurized with the facility-supplied Grade A helium through the auxiliary connect panel prior to engine restart.

3.1.3.1.3 <u>Chilldown System</u> - The chilldown system (MDAC-WD Drawing 1B45049) shall consist of the necessary valves to simulate operation of the vehicle LH_2 and LO_2 chilldown recirculation systems. Chilldown system components shall be mounted on the aft skirt thrust structure assembly and include flight-type valves and components. The LH_2 and LO_2 chilldown pumps are not used on the stage simulator. Their functions, however, shall be simulated as follows:

a. The chilldown motors, located on the aft skirt assembly, shall be electrically simulated in accordance with MDAC-WD Specification DS-2720. The chilldown inverter load simulator shall provide nominal electrical loading of the chilldown inverter.

b. The LH_2 and LO_2 tank chilldown shutoff valves shall be installed on simulated tank outlet ports.

c. Ambient air, controlled and regulated by the chilldown pump purge module, shall be provided to simulate the helium purge of the LO_2 pump motor housing. Controlled purge of the LO_2 pump motor housing shall be achieved by using a flight configuration solenoid-operated purge vent valve. A plenum chamber shall be provided to represent the LO_2 pump motor housing volume. The pump seal bleed function shall not be simulated.

LO_2 and LH_2 propellant fill and drain valves shall be provided and their functions simulated.

3.1.3.1.3.1 Chilldown Sequence - Chilldown of the LO_2 and LH_2 systems shall be accomplished in the following sequence.

a. Close the LO_2 and LH_2 propellant tank shutoff valves.

b. The chilldown emergency shutoff valves shall be in the open position to allow simulated propellant recirculation.

c. Open the main engine LO_2 and LH_2 bleed valves.

d. Start the chilldown motor simulators.

e. Simulate propellant circulation prior to simulated main engine ignition.

3.1.3.1.4 Auxiliary Propulsion System - Two auxiliary propulsion system (APS) simulators shall be provided to simualte the major functions of the two S-IVB/V flight APS units (see also 3.1.5.3.5). The No. 2 APS shall be an electricall-simulated unit in accordance with MDAC-WD Specification DS-2725..The No. 1 APS simulator shall be an operational unit containing flight-configurated components, except as noted herein (see Figure 3), in a prototype structure in lieu of a flight configurated structure.

The No. 1 APS simulator utilizes air for pressurant and propellant simulation, thereby allowing the omission of the positive expulsion bladders in the simulated APS propellant tanks. Since both the oxidizer and fuel feed systems are pressurized by a common pressure source, the fuel side has been disconnected and the oxidizer side of the APS engines orificed to allow a pressurant flowrate corresponding to the total propellant flowrate. The No. 1 APS simulator engines shall consist of three 150-pound thrust engines for roll, pitch, and yaw control simulation and a 70-pound thrust engine for fuel ullage control simulation; the engine shall incorporate flight-configurated propellant valves and injectors.

The APS high pressure vessel shall be charged with 3,100 psia air in lieu of helium. Air pressure to the propellant feed system (fuel side only) shall be regulated by the APS pressure control module and flow through a plenum chamber, propellant tank, and through the respective APS engines upon actuation of the propellant control valves. APS propellant loading shall not be simulated; however, flight configuration service connections shall be provided. Design of the No. 1 APS simulator shall be in accordance with MDAC-WD Drawing 1B45050.

3.1.4 Hydraulic System - The simulated main engine hydraulic control system (MDAC-WD Drawing 1B45066) shall provide the hydraulic power to achieve the desired functions during checkout and simulated flight operations (see Figure 5). This system shall not contain the main engine driven pump. The hydraulic power required to control and center the engine during simulated thrust buildup and thrust vector positioning during powered flight shall be provided by MSFC facility source in accordance with MDAC-WD Drawing 1A67970. Air pressurant and electrical power for the auxiliary pump shall be provided by MSFC facility in accordance with MDAC-WD Drawing 1B45202. The basic configuration of the major components, as described herein, shall be flight-type. Inactive measurements normally experienced under flight

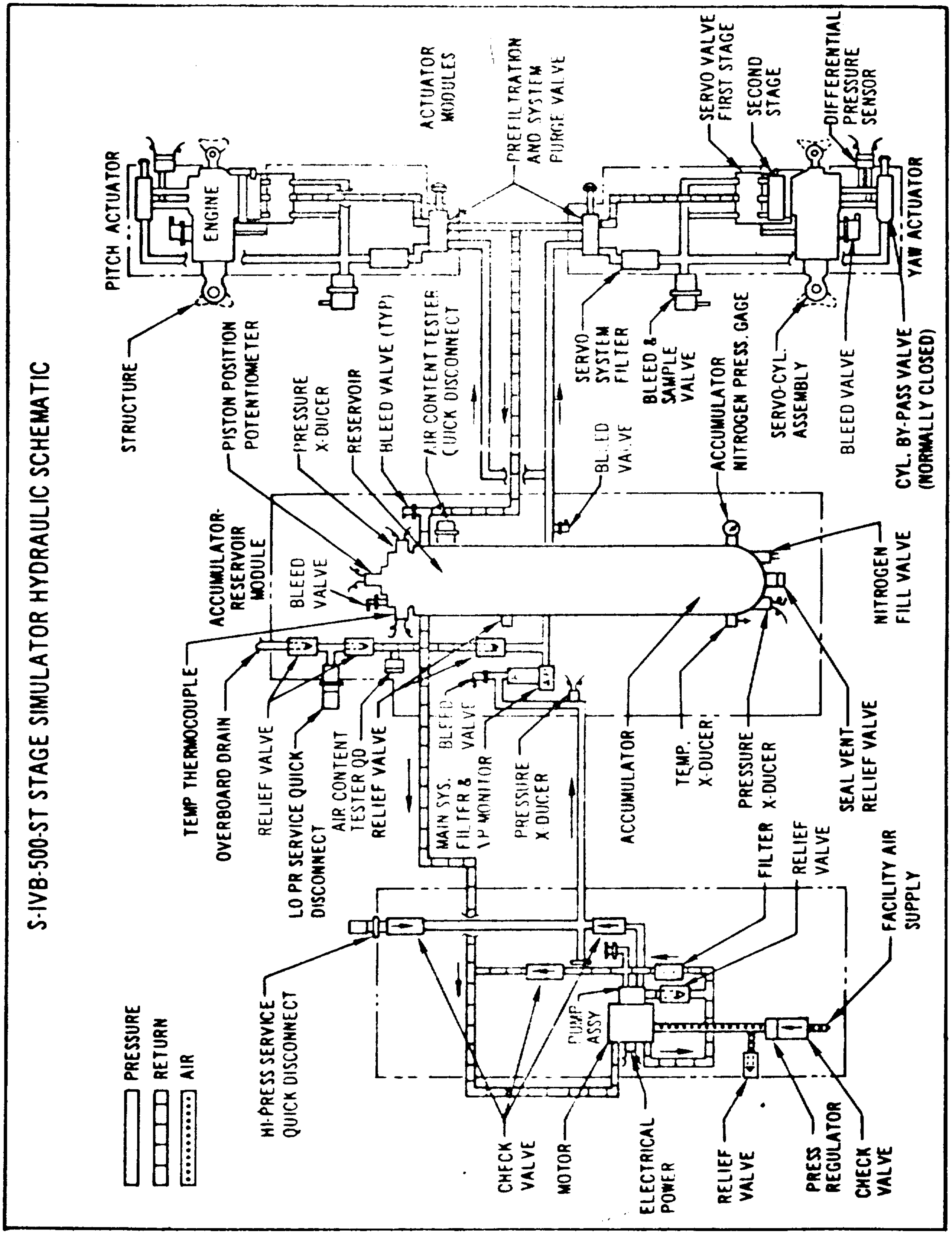
S-IVB-500-ST STAGE SIMULATOR HYDRAULIC SCHEMATIC
PRESSURE
RETURN
AIR
PITCH ACTUATOR
ENGINE
ACTUATOR MODULES
PREFILTRATION AND SYSTEM PURGE VALVE
SERVO VALVE FIRST STAGE
SECOND STAGE
DIFFERENTIAL PRESSURE SENSOR
YAW ACTUATOR
STRUCTURE
PISTON POSITION POTENTIOMETER
PRESSURE X-DUCER
RESERVOIR
BLEED VALVE (TYP)
AIR CONTENT TESTER QUICK DISCONNECT
SERVO SYSTEM FILTER
BLEED & SAMPLE VALVE
ACCUMULATOR NITROGEN PRESS. GAGE
SERVO-CYL. ASSEMBLY
BLEED VALVE
CYL. BY-PASS VALVE (NORMALLY CLOSED)
BLEED VALVE
ACCUMULATOR-RESERVOIR MODULE
BLEED VALVE
NITROGEN FILL VALVE
TEMP THERMOCOUPLE
OVERBOARD DRAIN
RELIEF VALVE
LO PR SERVICE QUICK DISCONNECT
AIR CONTENT TESTER QD
RELIEF VALVE
MAIN SYS. FILTER & ΔP MONITOR
BLEED VALVE
PRESSURE X-DUCER
ACCUMULATOR
TEMP. X-DUCER
PRESSURE X-DUCER
SEAL VENT RELIEF VALVE
HI-PRESS SERVICE QUICK DISCONNECT
FILTER
RELIEF VALVE
PUMP ASSY
FACILITY AIR SUPPLY
CHECK VALVE
MOTOR
ELECTRICAL POWER
RELIEF VALVE
PRESS REGULATOR
CHECK VALVE

FIGURE 5

environment conditions shall be simulated by the Measurement Simulator, MDAC-WD Specification DS-2722.

3.1.4.1 Hydraulic Fluid Contamination Level - The stage simulator hydraulic system shall be designed to operate with hydraulic fluid conforming to Specification MIL-H-5606. The hydraulic fluid shall be within acceptable contamination limits of MDAC-WD Drawing 1P00068.

3.1.4.2 Auxiliary Pump - The auxiliary electric motor-driven hydraulic pump shall provide hydraulic power to simulate ground-hold and coast phase of flight. The pump shall be capable of periodic operation for recirculation of the hydraulic system fluid to simulate flight environment conditions during the coast phase.

3.1.4.3 Reservoir/Accumulator Assembly - The reservoir shall be a low pressure accumulator capable of providing for system leakage losses, absorb pressure changes from return line surges, and serve as a storage reservoir when the high pressure accumulator is discharged. The reservoir shall also be capable of utilizing system pressure to pressurize the inlet to the pump. The high pressure accumulator, as an energy storing device, shall provide the system with instantaneous flow demands, dampen system pulsations, and maintain system pressure during pump acceleration and idling periods.

3.1.4.4 Pitch and Yaw Actuators - The double-acting, hydraulic linear actuators shall provide engine gimbaling capability for centering the engine and maintaining thrust vector control during simulated flight. The gimbal planes for the actuators shall be located 90 degrees apart. The servo valve, upon receipt of electrical guidance signals, shall provide hydraulic fluid flow to the actuators which in turn move the engine, thereby directing the thrust vector. Feedback to close the two servo loops shall be accomplished by electrical position potentiometers installed in each actuator package.

3.1.5 Electrical Systems - The basic flight electrical systems, interconnecting networks, and components shall be as specified in MDAC-WD Specification DS-2163. Simulator peculiar portions of these systems shall be as described herein. The stage simulator electrical block diagram is shown in Figure 6.

3.1.5.1 Power Distribution System - Flight configuration battery assemblies shall not be provided with the stage simulator; however, normal battery mounting structures and harnesses shall be provided. Receptacles shall be provided on the battery instrumentation simulators (described in 3.1.5.4.9 of this specification) where external MSFC power supplies may be connected to simulate the cells which are normally a part of the flight configuration battery assembly. A simplified schematic for this arrangement is shown in Figure 7. The power distribution system schematic shall be as shown in MDAC-WD Drawing 1B45830.

3.1.5.2 Electrical Installation -

3.1.5.2.1 Forward Skirt - Installation of electrical equipment such as panel mounted equipment, static inverters, distribution boxes, and the central grounding system shall be installed in accordance with MDAC-WD Drawing 1B45110. The

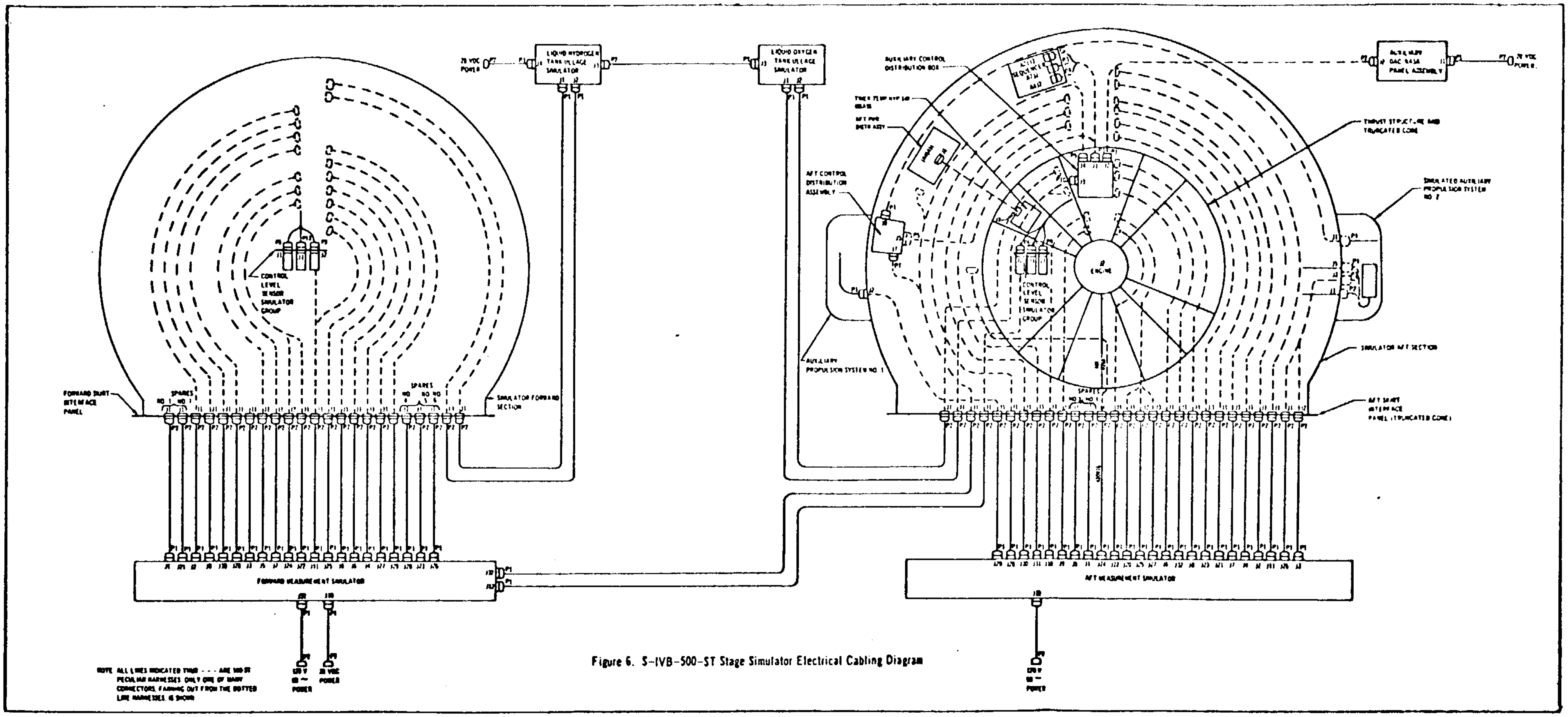

Figure 6. S-IVB-500-ST Stage Simulator Electrical Cabling Diagram

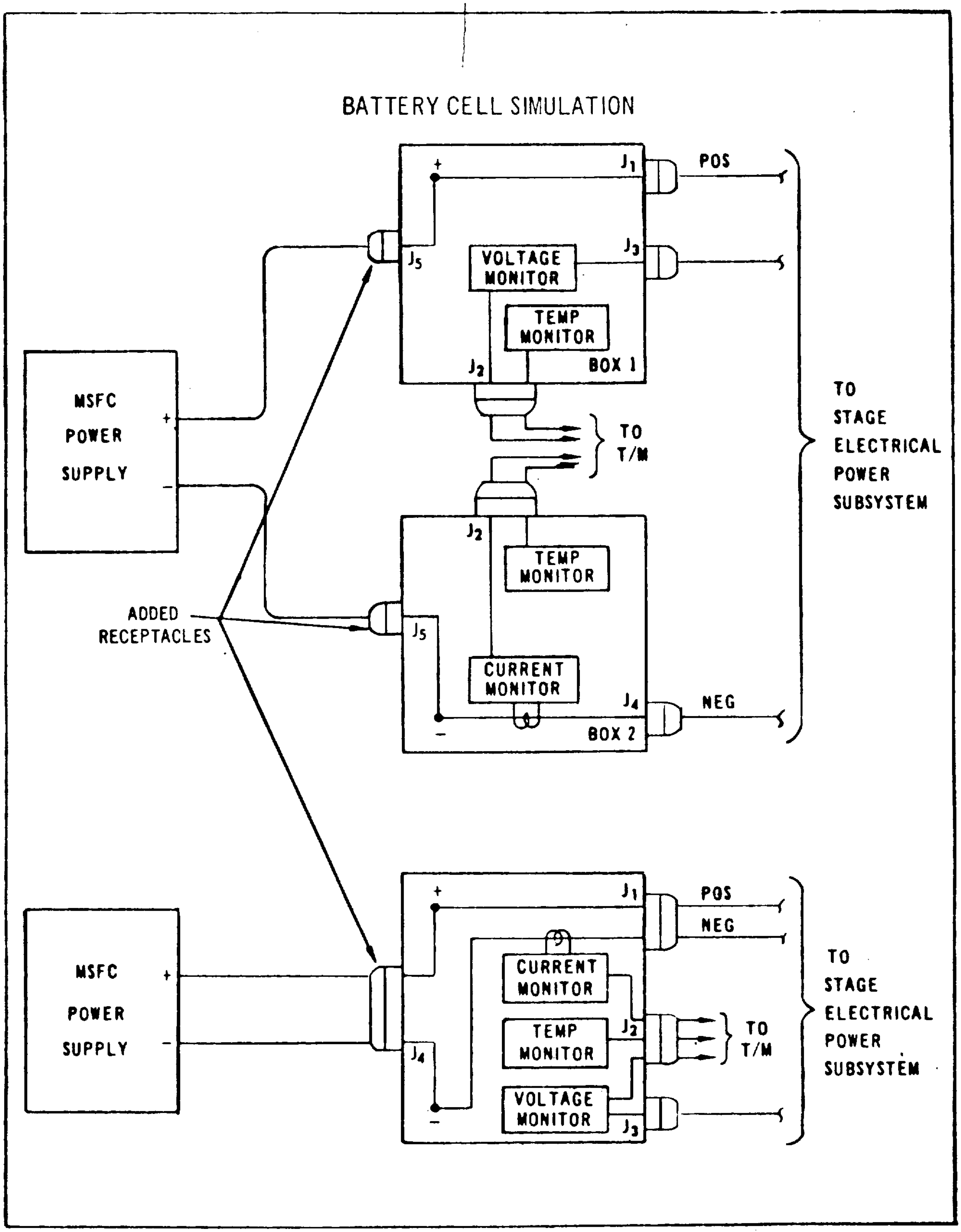
BATTERY CELL SIMULATION
MSFC POWER SUPPLY
+
-
POS
J1
J3
J5
J2
VOLTAGE MONITOR
TEMP MONITOR
BOX 1
TO T/M
TO STAGE ELECTRICAL POWER SUBSYSTEM
ADDED RECEPTACLES
CURRENT MONITOR
J4
NEG
BOX 2
MSFC POWER SUPPLY
POS
NEG
CURRENT MONITOR
TEMP MONITOR
VOLTAGE MONITOR
TO T/M
TO STAGE ELECTRICAL POWER SUBSYSTEM

FIGURE 7

related wiring harness installation shall be installed in accordance with MDAC-WD Drawing 1B45112.

3.1.5.2.2 Aft Skirt - Installation of electrical equipment such as power distribution assemblies, control distribution assemblies, chilldown inverters and the central grounding system shall be installed in accordance with MDAC-WD Drawing 1B45063. The related wiring harness installation shall be installed in accordance with MDAC-WD Drawing 1B45062.

3.1.5.2.3 Tunnel - The tunnel wiring harness installation shall be installed in accordance with MDAC-WD Drawing 1B45175.

3.1.5.3 Electrical Control Systems -

3.1.5.3.1 Engine Start System - The engine start system shall be modified to "T" out the engine start signal generated by the MSFC Instrument Unit and route it to the Propellant Utilization Dynamic Mass Simulator (MDAC-WD Specification DS-2719), the LH_2 ullage simulator, the LO_2 ullage simulator, and MDAC-WD/MSFC auxiliary connect panel. These signals shall be used to control stage simulator-peculiar functions. The engine start system schematic shall be as shown in MDAC-WD Drawing 1B45180.

3.1.5.3.2 Engine Cutoff System - The engine cutoff system shall be modified to "T" out the cutoff signal and route it to the propellant utilization dynamic mass simulator, the LH_2 ullage simulator, the LO_2 ullage simulator, and MDAC-WD/MSFC auxiliary connect panel. These signals shall be used to control stage simulator peculiar functions. Depletion sensors (three per tank) shall be simulated by switching in a wet capacitor as a function of the sensor electronics arm command and then dropping out of the capacitor after a predetermined and adjustable time delay. The time delay relays for these functions shall be packaged in small boxes mounted near the sensor electronics package. The arm and GSE checkout functions shall be teed out to operate these circuits. The engine cutoff system schematic shall be as shown in MDAC-WD Drawing 1B45181.

3.1.5.3.3 <u>Electrical Control Components - LH_2 Tank Pressurization System</u> - The following electrical switches and control modules are components of the flight vehicle LH_2 tank pressurization system (see 3.1.3.1.1.2). Design requirements and functional characteristics shall be as specified in MDAC-WD Specification DS-2724.

a. LH_2 Tank Pressure Control Module shall provide control of the LH_2 tank pressurization during prepressurization and simulated powered flight.

b. LH_2 Tank Repressurization Control Module shall provide control of the LH_2 tank repressurization prior to second burn.

c. Directional Control Module shall operate the directional (selective) control vent valve.

d. Vent Valve Module shall control the non-propulsive vent valve.

e. Propulsive Vent Valve Module shall control the propulsive vent valve for continuous venting.

f. Pad Safety Switch shall provide indication of a pressurized tank and feedback information to the stage simulator sequencer and GSE.

g. Liquid Hydrogen Loading Switch shall prevent additional fuel from being loaded if tank pressure exceeds the limits of this switch and provide feedback information to the stage simulator sequencer and GSE.

h. Prepressurize and Minimum Liftoff Switch, working in conjunction with the LH_2 Pressure Control Module, shall maintain the pressure within the limits of this switch for prepressurization minimum liftoff indication and provide feedback information to the stage simulator sequencer and GSE.

i. Repressurize and Second Burn Control Switch, working in conjunction with the LH_2 Tank Repressurization Control Module and LH_2 Tank Pressurization Control Module, shall maintain the pressure within the limits of the switch prior to and during second burn and provide feedback information to the stage sequencer and GSE.

j. Translunar Coast Switch shall initiate tank venting to a low pressure after second burn and provide feedback information to the stage simulator sequencer and GSE.

k. First Burn Control Switch, working in conjunction with the LH_2 tank pressurization module, shall maintain the pressure within the limits of the switch during first burn and provide feedback information to the stage sequencer.

1. Orbital Vent Makeup Switch (simulator peculiar) shall control the orbital vent shutoff valve (simulator peculiar) during the orbital coast phase.

The fuel tank pressurization system schematic shall be as shown in MDAC-WD Drawing 1B45828.

3.1.5.3.4 Electrical Control Components - LO_2 Tank Pressurization System - The following electrical switches and control modules are components of the flight vehicle LO_2 tank pressurization system (see 3.1.3.1.1.1). Design requirements and functional characteristics shall be as specified in MDAC-WD Specification DS-2723.

a. LO_2 Tank Pressure Control Module shall provide control of the LO_2 tank pressurization during prepressurization and simulated powered flight.

b. LO_2 Tank Repressurization Control Module shall provide control of the LO_2 tank repressurization prior to second burn.

c. Pad Safety Switch shall provide indication of a pressurized tank and feedback information to the stage simulator sequencer and GSE.

d. Vent Valve Module shall provide control of the vent valve which in turn allows tank venting to the facilities venting system and provide positional feedback to the GSE.

e. LO_2 Loading Switch shall prevent additional fuel from being loaded if tank pressure exceeds the limits of this switch and provide feedback information to the stage simulator sequencer and GSE.

f. Minimum Liftoff Switch shall provide indication of a minimum tank pressure required for liftoff to GSE.

g. Prepressurize, Flight Control and Repressurize Switch shall control pressure level in the LO_2 tank ullage simulator during prepressurization, both burn phases and repressurization phase.

h. The Translunar Vent Control Switch shall control pressure in the LO_2 tank ullage simulator following the second burn phase, during the translunar coast phase.

The LO_2 tank pressurization system schematic shall be as shown in MDAC-WD Drawing 1B45730.

3.1.5.3.5 Attitude Control System - Auxiliary Propulsion System No. 1 (APS) (see 3.1.3.1.4) circuits shall be similar to the flight APS. Wiring harness installation shall be adapted to structural difference of the simulator as opposed to the flight APS. APS No. 2 shall be electrically simulated as specified in MDAC-WD Specification DS-2725. The APS No. 2 simulator shall be packaged in a sheet metal box and mounted on the aft skirt in the same position as the flight APS. The attitude control system schematic shall be shown in MDAC-WD Drawing 1B45697.

3.1.5.3.6 Flight Control System - The flight control system shall be flight configuration. The system shall be capable of providing inflight steering and control during simulated powered flight or boost portion of flight. Design requirements and performance characteristics shall be as specified in MDAC-WD Specification DS-2163. The flight control system schematic shall be as shown in MDAC-WD Drawing 1B45726.

3.1.5.3.7 Exploding Bridgewire System (EBW) - An EBW electronic firing system shall be provided for the stage simulator. System design shall be as specified in MDAC-WD Specification DS-2163 with the following exceptions:

a. The ordnance portion of the EBW system shall not be required.

b. The exploding bridgewires associated with the range safety systems shall be simulated by an MSFC-furnished pulse sensor MDAC-WD installed), which shall provide a 28 volt dc signal to the stage simulator GSE when the firing unit pulse is applied during checkout. The pulse sensor shall also function as a load to the firing unit during simulated flight. Verification of operation shall be provided through telemetry by a signal from the firing unit monitor output circuit.

The EBW system schematic shall be as shown in MDAC-WD Drawing 1B45831.

3.1.5.3.8 Stage Simulator Sequencing - The stage simulator sequencer, located in the aft skirt assembly, shall be flight-type. The sequencer shall provide control of the succession of events during inflight simulation. The sequencer shall not provide programming capabilities, but it shall contain circuits to provide proper response to commands received from the MSFC Instrument Unit. Various commands shall be teed out of the existing vehicle harness to supply timing commands for the LH_2 ullage simulator, LO_2 ullage simulator, and MDAC-WD/NASA auxiliary connect panel as required. Design requirements and performance characteristics shall be as specified in MDAC-WD Specification DS-2163. The stage simulator sequence of events diagram shall be as shown in MDAC-WD Drawing 1B45182.

3.1.5.3.9 Propellant Utilization Flight System - Depletion of propellants as normally sensed by the PU probe shall be simulated in the mass simulator by a predetermined depletion rate program which is controlled by the engine start, engine restart and engine cutoff signals in the vehicle. The electrical output of the propellant utilization (PU) system servo amplifier in the stage simulator shall be wired out to the PU Dynamic Mass Simulator (MDAC-WD Specification DS-2719) where it shall be used to drive the main engine valve positioner simulator. A position feedback signal from the main engine valve positioner simulator shall be routed back to the summing and shaping module in the stage simulator. The propellant utilization flight system schematic shall be as shown in MDAC-WD Drawing 1B45723.

3.1.5.3.10 Propellant Utilization (PU) Loading System - The PU probe function shall be provided by a capacitance, simulating the empty tank, and a connector through which the simulated propellant level capacitance program is routed. The overfill sensors on each tank shall be simulated by a dry capacitor and another capacitor which can be switched in by a manual switch to simulate the wet valve. The switch and capacitors shall be located in the respective skirt assembly in the proximity of the normal flight sensors.

Fast fill sensors shall be switched from dry to wet by utilizing 28 VDC "98 percent full" signals from the PU Mass Simulator. These signals shall be routed to the respective sensor electronics to add the ground checkout capacitor. The fill solenoid functions from each of the fill and drain modules shall be brought out to the PU Dynamic Mass Simulator to control the fill programs of the stage simulator. The propellant utilization loading system schematic shall be as shown in MDAC-WD Drawing 1B45287.

3.1.5.3.11 Data Acquistion System - The data acquisition system shall be of flight configuration and shall consist of one system utilizing one basic modulation scheme: Pulse Code Modulation, Frequency Modulation (PCM/FM):

a. The PCM/FM system shall provide digital information for automatic checkout and simulated flight performance evaluation.

Design requirements and performance characteristics shall be in accordance with MDAC-WD Specification DS-2163. The data acquisition system schematic shall be as shown in MDAC-WD Drawing 1B45832.

3.1.5.3.12 Range Safety Systems - The range safety systems of the stage simulator shall be identical to those systems of the S-IVB/V flight stage as specified in MDAC-WD Specification DS-2163 with the exception that no ordnance shall be required. (see 3.1.5.3.7 of this specification). Design requirements and performance characteristics shall be in accordance with MDAC-WD Specification DS-2163 except that the safety and arming device shall be inert. Range safety systems No. 1 and 2 schematic shall be as shown in MDAC-WD Drawing 1B45833 and 1B45834, respectively.

3.1.5.3.13 Auxiliary Hydraulic Pump - In order to simulate the periodic "on-off" cycling of the auxiliary hydraulic pump in the coast mode of the hydraulic system, a timing device shall replace the oil temperature thermostat. This device shall cycle the pump upon receipt of a coast mode "on" signal. The "on-off" period shall be adjustable, and shall be capable of being set at 4.4 minutes "on" and fifty-two minutes "off". Refer to MDAC-WD Drawing 1B45829 for the schematic of auxiliary hydraulic system.

3.1.5.4 Electrical Instrumentation System - The active stage simulator measurement transducers shall be functionally identical to the corresponding transducers in the S-IVB/V flight stage. Inactive measurements shall be simulated and are defined as follows:

a. Measurements for which the physical location is not included as part of the stage simulator.

b. Measurements for which no active input is provided to the transducer, with one exception: measurements are considered active if the low end of the expected ambient temperature range is greater than 5 percent or the high end less than 95 percent of that portion of the transducer working range scaled for telemetry.

The Measurement Simulator (MDAC-WD Specification DS-2722) shall provide simulation for the majority of those measurements listed as inactive in the stage simulator Instrumentation Program and Components List (IPCL) (MDAC-WD Drawing 1B46203). Included in the inactive list are measurements in the structure, fuel, oxidizer, engine, PU, ullage, auxiliary propulsion, hydraulic, and helium instrumentation systems. The inactive measurements not simulated in the measurement simulator, such as propellant point level and APS No. 2 temperature measurements, shall be simulated in the skirt and APS simulators, respectively.

Simulated transducer signals generated in the measurement simulator shall be brought into the stage simulator through added disconnect panels and shall be connected to the stage simulator instrumentation system at the points where transducers would normally be connected.

3.1.5.4.1 <u>Instrumentation Miscellaneous Measurement System</u> - Miscellaneous measurements include transmitter power, battery power, battery temperature, position, flow, turbine speed, frequency, excitation voltage, ratio and signal strength measurements. Turbine speed and flow measurements transducers are simulated. The miscellaneous measurements instrumentation system schematic shall be as shown in MDAC-WD Drawing 1B46218.

3.1.5.4.2 <u>Instrumentation Temperature Measurements System</u> - Temperature measurements of cryogenics and certain other temperature measurements on inactive systems shall, in general, be simulated. Where possible temperature sensors shall be considered active at room ambient (see 3.1.5.4.b). The temperature measurements system instrumentation schematic shall be as shown in MDAC-WD Drawing 1B46219.

3.1.5.4.3 <u>Instrumentation Pressure Measurements System</u> - Pressure measurements normally located in the fuel and LOX system which are associated with ullage functions active on the ullage simulators, shall be relocated on those simulators. Certain other pressure measurements shall be simulated. The pressure measurements instrumentation system schematic shall be as shown in MDAC-WD Drawing 1B46220.

3.1.5.4.4 <u>Instrumentation Bi-Level Measurements System</u> - Bi-Level measurements normally located in the fuel and oxidizer system, which are associated with ullage functions active on the ullage simulators, shall be relocated on those simulators. Fuel and oxidizer point level sensors shall be simulated by a dry valve capacitor installed at the level sensor bulkhead connector. The bi-level measurements instrumentation system schematic shall be as shown in MDAC-WD Drawing 1B46221.

3.1.5.4.5 Instrumentation Voltage and Current Measurement System - Measurements normally located in the propellant utilization dynamic mass simulator system, the chilldown inverter load simulator, and the EBW ullage rocket system shall be relocated to where these systems are simulated. The voltage and current measurements instrumentation system schematic shall be as shown in MDAC-WD Drawing 1B46222.

3.1.5.4.6 Instrumentation Dual Repressurization Measurement System - Active pressure and bi-level measurements normally located in the dual repressurization system, shall be relocated to the dual repressurization simulator system. Other functions such as temperature, heat flux, some pressures shall be simulated. The dual repressurization measurements insturmentation system schematic shall be as shown in MDAC-WD Drawing 1B46223.

3.1.6 Thermo-Conditioning System for Panel Mounted Equipment - A complete production type thermo-conditioning system shall serve the electrical-electronic equipment located in the forward skirt section of the stage simulator. The system shall consist primarily of 15 cold plates (heat exchangers), rigid piping, flexible hoses, and two quick disconnect couplings. The cold plates shall attach to the structure through vibration isolators. The system shall interface with the MSFC Instrument Unit thermo-conditioning system through two quick disconnect couplings. A temperature controlled fluid shall be circulated from the MSFC Instrument Unit through the cold plates on which the electrical-electronic equipment is mounted and returned to the Instrument Unit.

3.1.7 Operability -

3.1.7.1 Reliability - A high inherent reliability shall be designed into the stage simulator through the application of good reliability design practices.

3.1.7.2 Maintainability - The stage simulator shall be constructed so that all parts (except in the case of sealed units), terminals and wiring are accessible for checking, adjustment, and repair with a minimum of disturbance to other parts and with minimum use and variety of special tools. Adjustments required shall be the minimum consistent with required performance. Wherever possible, parts shall be mounted so that they can be removed and replaced without interference from, damage to, or removal of other parts or wiring. Parts most likely to fail (based on reliability analysis or parts history) shall be easily replaced.

3.1.7.3 Human Factors Engineering - Human factors engineering criteria specified in MDAC-WD Drawing 1A02680 shall be applied throughout the design and development of the stage simulator to ensure optimum personnel performance in control, operation, and maintenance.

3.1.7.4 Service and Access - The stage simulator peculiar structural assemblies shall feature doors and access panels to permit ease of access for service.

3.1.7.5 Useful Life - The overall design concept of the stage simulator shall be based upon good engineering practices with an intended life span of approximately 3 years with routine refurbishment. The applicable useful life of the individual simulators referred to in this specification shall be in accordance with the applicable MDAC-WD Specification listed in 2. of this specification.

3.1.7.6 Natural Environment - The stage simulator shall be operated indoors, with a temperature range of 50 to 110°F, a relative humidity from 0 to 95 percent, and the ambient atmospheric pressure of the testing or using facility.

3.1.7.7 Transportability - The transportability requirements for packaging, packing and delivery are not applicable to 504N Configuration.

3.1.7.8 Personnel Safety - Personnel safety shall be maintained by compliance with applicable pressure vessel manufacturing codes and operating procedures. Any operations on hardware peculiar to the stage simulator shall be monitored to reduce or eliminate potential hazards consistent with contract requirements.

3.1.7.9 Induced Environment - The stage simulator shall be capable of withstanding the minimum shock and vibration environments induced by reworking structural and mounting brackets.

3.2 Stage Simulator Definition -

3.2.1. Interface Requirements - The stage simulator shall simulate checkout flight functions of the Saturn S-IVB/V flight stage and shall interface with the Saturn V Breadboard Facility at MSFC.

3.2.1.1 Schematic Arrangement - The following equipment is incorporated in the stage simulator as individual simulators which are covered in separate MDAC-WD Specifications listed herein. The electrical arrangement is shown in Figure 6. The Pressurant Storage Simulator, however, is not shown.

SIMULATOR	MDAC-WD SPECIFICATION NO.
Propellant Utilization Dynamic Mass Simulator	DS-2719
Measurement Simulator	DS-2722
Childown Inverter Load Simulator	DS-2720
LH_2 Tank Ullage Simulator	DS-2723
LO_2 Tank Ullage Simulator	DS-2724
Auxiliary Propulsion System Simulator	DS-2725
Pressurant Storage Simulator	DS-2726
Dual Repressurization	TBD

3.2.1.2 Detailed Interface Definition -

3.2.1.2.1 Electrical - Wiring from simulator peculiar peripheral equipment outside the forward and aft skirt assemblies shall enter the skirt assemblies by way of a disconnect panel. Functions of the disconnect panel shall be limited to simulator peculiar wiring. Active RF systems shall include the normal transmitters, antennas and closed loop coaxial fittings.

Facility furnished power shall consist of 120 volts $\pm$12 volts, 60 cycles per second (cps) $\pm$3 cps, 2.9 kilovolt amperes and 28 volts direct current (vdc) $\pm$2.8 v at 20 amperes. Additional battery power shall be provided by MSFC (see 3.1.5.1). Connector access to battery circuits shall be provided by MDAC-WD. MSFC and MDAC-WD interfaces are defined as follows:

a. Umbilicals: Electrical interface of the stage simulator and GSE at the forward and aft skirt assemblies electrical umbilicals shall conform to the requirements of MSFC Drawing 40M35001. The umbilical circuits shall present the normal electrical loads to incoming power and signals and shall provide responses to the GSE functionally identical to S-IVB/V flight stage defined in MSFC Drawing 40M35001, with the exception that instrumentation data which is generated in the measurement simulator shall reflect those measurement characteristics as specified in MDAC-WD Specification DS-2722.

b. Instrument Units: The MSFC Instrument and Stage simulator electrical interface shall conform to the requirements of MSFC Drawing 40M30597.

MDAC-WD connector reference designations, however, shall conform to MDAC-WD Drawing 1B45986.

c. S-II Stage: The S-II stage and the stage simulator electrical interface shall conform to the requirements of MSFC Drawing 40M30593.

d. J-2 Engine: The J-2 engine and the stage simulator electrical interface shall functionally conform to the requirements of MSFC Drawing 13M50406.

3.2.1.2.2 Stage Simulator and MSFC Facility Mechanical Interface - The stage simulator and MSFC facility interface shall be at the umbilical MDAC-WD/NASA auxiliary connect panels. The major interface requirements for the facility air and helium supplies shall be in accordance with the requirements of MDAC-WD Drawing 1B45227 and 1B45011.

A manifold vent system which shall have an interface with the MSFC facility shall be provided for safe venting of all high pressure gases from the subsystem components.

Interconnection of the stage simulator subsystem at MSFC shall be accomplished using a MDAC-WD furnished pipeline outfit kit which shall be installed in accordance with the requirements of MDAC-WD Drawing 1B45043. MDAC-WD shall be responaible for interconnection of the liquid oxygen tank ullage simulator, the liquid hydrogen tank ullage simulator, the pressurant storage simulator, and the aft skirt and thrust structure assemblies. All other interconnecting lines from MSFC facilities shall be provided by NASA.

3.2.2 Components Identification -

3.2.2.1 Government-Furnished Property List -

NOMENCLATURE	PART NO.
Control Relay Package	50M35076-1
Switch Selector-Mod 1	50M04008-1
Secure Command Receiver	50M10697
Secure Command Decoder	50M10698
Range Safety System Controller	40M32016-1
EBW Pulse Sensor	40M02852-1
EBW Firing Unit	40M39515-103
EBW Firing Unit	40M39515-107
J-2 Engine Simulator	103826 J206
J-2 Engine Simulator ECA	J2012
Gemini 70 Pound Thrust Engine	SE-64-1023
PCM/DDAS Assy Model 301	50M66512
Voltage Regulator	50M10419-1
Remote Analog Submultiplexer Assy.	50M10909
Safing Plug	40M32042-1
Remote Digital Submultiplexer Assy.	50M66595

3.3 Design and Construction - The design and construction of the stage simulator shall be as specified in Standard MSFC-STD-110, excluding paragraphs listed in "a through g" below. These paragraphs shall be complied with as follows:

a. Paragraph 4.2 "Soldering" of Standard MSFC-STD-110, as defined in 3.3.6.1 of this specification.

b. Paragraph 4.3 "Identification" of Standard MSFC-STD-110, as defined in 3.3.14 of this specification.

c. Paragraph 4.4 "Electrical design" of Standard MSFC-STD-110, as defined in 3.3.1 of this specification.

d. Paragraph 5.4 "Electrical components" of Standard MSFC-STD-110, as defined in 3.3.7 of this specification.

e. Paragraph 5.2.4.1 "Lettering" of Standard MSFC-STD-110, as defined in 3.3.8 of this specification.

f. Paragraph 5.2.4.1.1 "Style" of Standard MSFC-STD-110, as defined in 3.3.8 of this specification.

g. Paragraph 5.3 "Chassis" of Standard MSFC-STD-110, as defined in 3.3.9 of this specification.

3.3.1 <u>Electrical Engineering Design Practices</u> - Electrical Engineering design practices shall be in accordance with Standard MSFC-STD-163, excluding paragraphs listed in "a through d" below. These paragraphs shall be complied with as follows:

a. Paragraph 4.2 "Drawings" of Standard MSFC-STD-163, as defined in 3.3.1.1 of this specification.

b. Paragraph 5.1.2 "Connectors" of Standard MSFC-STD-163, as defined in 3.3.1.2 of this specification.

c. Paragraph 5.4.2 "Circuits carrying dc" of Standard MSFC-STD-163, as defined in 3.3.1.3 of this specification.

d. Paragraph 5.4.4 "Connector to terminal board" of Standard MSFC-STD-163, as defined in 3.3.1.4 of this specification.

3.3.1.1 Drawings - All drawings provided as official documentation shall be prepared with symbols and abbreviations specified in Standard MSFC-STD-110 and in accordance with MDAC-WD drafting practices.

3.3.1.2 Connectors - Each contact of a box-mounted connector shall be individually terminated at a terminal board, whenever practicable.

3.3.1.3 Circuits Carrying DC - The sequence of connector contracts carrying positive and negative circuit leads shall be optional.

3.3.1.4 Connector to Terminal Board - The sequence of wiring of connector contacts to the respective terminal board terminals shall be optional.

3.3.2 Weight and Center of Gravity - Not applicable for the 504N configuration.

3.3.3 Structural Design Criteria - Strength shall be provided throughout all structure assemblies to withstand all design conditions during handling and operations. However, it is not required that the structural stiffness characteristics simulate that of flight hardware. No permanent deformation at limit or applied load which would be detrimental to the performance characteristics of the stage simulator shall be permitted.

3.3.4 Safety Factors - The following safety factors shall be applicable to the simulated flight vehicle portion of the stage simulator structural design as minimum values:

a. General Structure - ground handling:
   Yield Factor of Safety = 1.10
   Ultimate Factor of Safety = 1.40

b. Hydraulic and Pneumatic Systems:
   Flexible Hose, Tubing, and Fittings less than or equal to 1.5 inches diameter:
   Proof Pressure 2.00 x Maximum Operating Pressure
   Burst Pressure 4.00 x Maximum Operating Pressure
   Flexible Hose, Tubing, and Fittings greater than 1.5 inch diameter:
   Proof Pressure 1.50 x Maximum Operating Pressure
   Burst Pressure 2.50 x Maximum Operating Pressure

c. Pneumatic and Hydraulic Reservoirs:
   Proof Pressure 1.50 x Maximum Operating Pressure
   Burst Pressure 2.50 x Maximum Operating Pressure

3.3.4.1 Safety Factors - Ground Support Equipment - The following safety factors shall be applicable to the GSE portion of the stage simulator structural design as minimum values:

a. General Structures:

Yield Factor of Safety = 1.00

Ultimate Factor of Safety = 1.50

b. Pneumatic and Combined Pneumatic - Hydraulic Systems:

Proof Pressure 1.50 x Maximum Operating Pressure

Yield Pressure 2.00 x Maximum Operating Pressure

Burst Pressure 4.00 x Maximum Operating Pressure

3.3.5 Selection of Specifications and Standards - Specifications and standards not specifically noted herein, and which become necessary for the design or manufacture of the stage simulator, shall be selected in the order of precedence established in Standard MIL-STD-143 and contractual requirements, giving consideration to economic factors, and providing that the functional adequacy of the stage simulator is not adversely affected.

3.3.6 Materials, Parts, and Processes -

3.3.6.1 Soldering - Soldering shall be in accordance with Procedure MSFC-PROC-158, excluding paragraphs listed in "a through e" below. These paragraphs shall be complied with as follows:

a. Paragraph VI-A-1-b "Flux" of Procedure MSFC-PROC-158 as defined in 3.3.6.1.1 of this specification.

b. Paragraph VI-A-1-e "Solvent" of Procedure MSFC-PROC-158 as defined in 3.3.6.1.2 of this specification.

c. Paragraph VI-A-2-a-(1) "Thermal stripper" of Procedure MSFC-PROC-158 as defined in 3.3.6.1.3 of this specification.

d. Paragraph VI-A-3-d-(2) "Insulation clearance" of Procedure MSFC-PROC-158 as defined in 3.3.6.1.4 of this specification.

e. Paragraph VI-B-1-e "Flux" of Procedure MSFC-PROC-158 as defined in 3.3.6.1.1 of this specification.

3.3.6.1.1 Flux - Only non-corrosive and non-conductive rosin-type fluxes shall be used. Rosin (or resin) core flux shall have a melting point below the liquid temperature of the solder. The use of liquid rosin-type flux having non-corrosive non-conductive properties is permissible for applications such as the removal of excess solder from a joint by wicking into stranded wire, and for soldering nickel-plated wire. When used with flux-cored solder, the liquid flux shall be chemically compatible with the solder core. Excess flux shall be removed from solder joints with the solvent specified in 3.3.6.1.2 except that excessive flux remaining on rotary switches, Janco switches, micro switches, potentiometers, circuit breakers and connectors with non-removable contacts shall not be removed with solvents. Excess flux on these items shall be removed with a stiff bristled non-metallic brush or a blunt non-metallic instrument.

3.3.6.1.2 <u>Solvent</u> - Except as specified in 3.3.6.1.1 of this specification, the solvents used for the removal of grease, oil, and excess flux shall be one of the following:

a. Ethyl alcohol, conforming to Specification MIL-E-463.

b. Isopropyl alcohol, conforming to Specification TT-I-735 Grade A.

c. Chlorothene, conforming to Specification O-T-620.

3.3.6.1.3 <u>Thermal Stripper</u> - Precision mechanical strippers shall be permitted for use on all gages of wires insulated with braided glass or other insulation material which cannot be stripped by thermal methods.

3.3.6.1.4 <u>Insulation Clearance</u> - Minimum insulation clearance shall be 1/32-inch. The maximum insulation clearance shall be the outside diameter of the insulated wire with a tolerance of +1/32-inch.

3.3.6.1.5 <u>Technique</u> - Resistance soldering equipment and techniques such as those covered in NASA Handbook SP-5002, paragraph E.7, shall be permitted when soldering electrical connections where space limitations preclude use of soldering irons. Resultant solder joints shall meet the requirements of Procedure MSFC-PROC-158.

3.3.6.2 <u>Bonding</u> - Bonding of all parts shall be in accordance with Specification MIL-B-5087.

3.3.7 Electrical and Mechanical Components -

3.3.7.1 Standard and Commerical Parts - All parts of the stage simulator shall be selected from the approved parts list (MDAC-WD Drawing 1A57652 or 1A49909) whenever feasible. Unlisted parts may be used providing the functional adequacy of the stage simulator is not affected.

3.3.8 Lettering Style - Lettering style shall be Futura Medium.

3.3.9 Chassis - Chassis and supporting members shall be constructed of aluminum conforming to conditions 5052-0, 6061-T6, or 2024-T4 of Specifications QQ-A-318, QQ-A-327, or QQ-A-267, respectively.

3.3.10 Wiring - Wiring practices shall be in accordance with Specification ABMA-PD-E-53 except that 3.2.7 "Securing wiring bundles" shall read as follows:.... Spot ties may be substituted for continuous lace for wiring developed within the skirt areas and with subassemblies . . .

3.3.11 Interchangeability and Replaceability - All stage simulator parts having the same manufacturer's part number shall be directly and completely interchangeable with respect to installation and performance. Mechanical and electrical interchangeability shall exist between like assemblies, regardless of the manufacturer of supplier.

3.3.12 Workmanship - The stage simulator, including all parts, assemblies, and related simulator equipment shall be constructed and finished in a workmanlike manner. Particular attention shall be given to neatness of soldering, marking of parts, welding, brazing, plating, painting, riveting, machine screw assemblies, and freedom of parts from burrs and sharp edges.

3.3.13 Radio Frequency Interference - The design of the stage simulator shall be specified in paragraph 4.4.1 "Radio frequency interference" of Standard MSFC-STD-110.

3.3.14 Identification and Marking - Each major assembly and subassembly of the stage simulator shall include an identification plate in accordance with MDAC-WD Drawing 1B00405 or 1B00407, with the following minimum information:

a. Nomenclature

b. Part Number

c. Weight

d. Serial Number

e. Contract Number

Any additional markings and labels shall be as specified in MDAC-WD Drawing 1A66131. White nylon bands suitable marked (TY-RAPS) shall be used for identification of harness assemblies.

3.3.15 Finish - Corrosion protection and decorative finishes shall be applied as specified in Addendum I of MDAC-WD Specification F-289.

3.3.16 Cleaning - All piping and tubing shall be cleaned per MSFC Specification 164.

4. QUALITY ASSURANCE PROVISIONS

Not applicable. The MDAC-WD personnel will provide technical assistance to MSFC during the MSFC checkout of the 500ST/504N configuration.

5. PREPARATION FOR DELIVERY

Not applicable.

6. NOTES

Not applicable.

10. APPENDIX

Not applicable.